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COGENERATE WITH COKE

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I. Introduction

As refiners turn to heavier, more sour feedstocks, the production of fuel grade green coke from delayed cokers is increasing. The market for fuel grade coke in the United States is not strong, most of the fuel grade coke produced is exported. These market conditions create an environment where a cheap source of fuel is available for use in cogeneration facilities producing electricity and process steam for use in the coke producing refinery. The refinery steam and electricity requirements can be satisfied by the cogeneration plant and excess electricity can be sold to the local electric utility at avoided cost rates. The refinery gains by having an economical source of steam and electric power. Possibly of more importance, the refiner has a reliable means of disposing of petroleum coke with an economic return based upon the value of the steam and power produced in the cogeneration plant rather than the uncertain or low value that can be received in the fuel grade coke market.

This paper examines the technical and economic feasibility of a coke based cogeneration project for a U.S. Gulf Coast refinery. Cases are developed comparing coke based cogeneration with import of electricity and natural gas fuel to produce steam. Two coke

burning technologies are examined: a circulating fluid bed boiler and a pulverized coke fired boiler. The refinery is assumed to require 145 MW of electricity, 400,000 lb/hr of 600 psig steam and 1,200,000 lb/hr of 250 psig steam. Furthermore, it is assumed that the refinery produces 2800 T/D of coke that must be disposed of in the cogeneration plant.

II. Technologies for Burning Coke

Two technologies for burning petroleum coke to produce steam are considered. Both technologies are based upon adaptation to coke firing of well known commercial plant experience. They represent Combustion Engineering's continued efforts in developing boiler applications for fuels other than traditional gas, oil and coal.

Circulating Fluid Bed Boiler

The Lurgi/Combustion Engineering Circulating Fluid Bed (CFB) Boiler is a well developed commercial technology for producing steam. The CFB boiler has been developed to efficiently burn solid fuels previously considered environmentally unacceptable. These fuels include coal and lignite residue, anthracite culm, sludges and of interest here, petroleum coke.

The design of the CFB boiler avoids the need for installation of costly scrubbing facilities normally required for controlling sulfur oxide emissions. The inherently low combustion temperature in the CFB boiler has the advantage of low nitrogen oxide formation. The process assures stack emissions that meet stringent environmental regulations. Solid waste is in the form of a mixture of dry ash, calcium sulfate and calcined lime.

Combustion in a CFB boiler takes place in a vertical combustion chamber. Fuel and limestone are fed into the combustion chamber, fluidized, and burned at temperatures of 1500-1600°F. Limestone reacts with the sulfur dioxide released by burning the fuel to form calcium sulfate. The bed material in the combustion chamber consists primarily of calcium sulfate, excess calcined lime and ash from the fuel. Limestone is added at a conservative 1.6 Ca:S ratio to ensure greater than 90% removal of sulfur compounds.

The bed material is fluidized with primary air introduced through a grate at the bottom of the combustion chamber and by the combustion gases generated. Secondary air is added to the combustion chamber to achieve complete and staged combustion.

The velocities in the combustion zone of the CFB are set so that the combustion gases entrain a considerable amount of solids from the combustion chamber. The solids are separated from the gases in a cyclone and are returned to the bed directly or after passing through an external fluid bed heat exchanger (FBHE). High internal and external circulating solids rates characteristic of CFB's results in uniform temperatures throughout the combustion chamber and effective temperature control, facilitating good SO_2 control.

Long solids residence and contact times, with the high heat and mass transfer rates achieved, result in a high combustion efficiency. These conditions also allow both the complete decomposition of the limestone and subsequent capture of SO_2 at a low calcium to sulfur molar ratio. Staged combustion, at controlled low temperatures, effectively controls NO_x formation.

Heat for steam generation and superheat is removed from the combustion chamber walls, the FBHE, and a convective pass of heat exchangers including an economizer where heat is removed from the flue gas exiting the solids recycle cyclone. After passing the convective heat exchangers the

gases are further cooled in an air preheater. The flue gases are cleaned in a bag house to meet New Source Performance Standards for particulate emissions of 0.03 $lb/10^6$ BTU fired and then are vented via an induced draft fan and stack. Although higher efficiencies are expected, a conservative boiler efficiency of 88 percent (LHV) was assumed for this study.

Excess solid waste is removed from the system via a fluid bed cooler. Materials are removed from the fluidized bed in order to control solids inventory and remove sulfur oxides captured in the form of calcium sulfate. Material removed is taken offsite for disposal.

For more information on CFB boilers see references (1) and (2).

Pulverized Coke Boiler

The Combustion Engineering Pulverized Coke Boiler (PCB) is a design adapted from Combustion Engineering's long experience with conventional pulverized coal burning boilers. Changes are made from standard coal burning boilers to handle the low ash, high metals, and low volatiles content of the coke.

Petroleum coke is pulverized and burned with primary air in a modified tangentially fired boiler. Secondary air and recycled flue gas are added to the combustion radiant chamber to help minimize NO_x formation. Modifications to standard coal boiler design include larger fire box volume to increase the residence time which is required for complete burn out of the low volatiles containing coke, and refractory lining portions of the radiant fire box to protect the tubes from high corrosion due to the high sulfur and vanadium content of the coke. Supplementary firing with natural gas at a rate of 5% of the fuel value of coke is included to ensure complete combustion.

Ash and combustion gases pass overhead into convective heat exchangers for additional steam generation, superheating and economizer. The gases are passed through an air preheater. Ash is then removed in a venturi scrubber before the flue gases are scrubbed for sulfur oxides removal in an Air Quality Control System (AQCS) followed by a wet precipitator for acid mist removal. Limestone is added to the AQCS for sulfur oxides removal. The waste stream from the AQCS is a gypsum sludge containing fly ash at approximately 30% water content. Overall thermal efficiency for the PC Boiler was taken as 88 percent, similar to the CFB.

Coke Quality

Coke fuel for both of the boiler cases is based upon the following typical fuel grade coke characteristics:

Volatile content	12.5%
Sulfur	7%
Moisture	10%
Ash	0.2%
Heating Value BTU/lb (HHV)	15,000
Hardgrove grindability	70

These characteristics are similar to that of an anthracite coal except ash is much lower and Hardgrove grindability is higher (i.e., coke is more friable).

III. Description of Power Cycles

High pressure superheated steam from the coke fueled boilers is fed to turbogenerators for production of electricity and steam. Steam is extracted at nominally 610 psig to supply 400,000 lb/hr of 600 psig steam to the refinery. Steam at nominally 260 psig

is extracted to supply 1,200,000 lb/hr of 250 psig steam to the refinery and to satisfy boiler feed water preheating requirements. Extraction steam at nominally 50 psig is used to strip dissolved gases from the BFW in the deaerator. Flash steam from boiler blowdown is also used by the deaerator. Steam from the exhaust of the turbine is condensed at 3.5 inches mercury absolute against cooling water. A diagram of the overall power cycle is shown in Figure 1.

It is assumed that fifty percent of the steam exported to the refinery will be returned as condensate. The condensate and makeup water are treated to remove dissolved solids and then fed to the deaerator. In the deaerator the water is stripped of dissolved gases. The water is then pumped, pre-heated against 260 psig steam and fed to the boiler.

Electricity is generated by the turbogenerators at 13.8 KV. A certain amount of electricity is used in the cogeneration plant for water treatment, cooling tower, materials handling, waste treatment, etc. This power is fed to transformers within the cogeneration plant and used internally. Excess power is exported to the refinery and the utility at 13.8 KV. In this analysis the refinery requires 145 MW of power.

FIGURE 1

POWER CYCLE

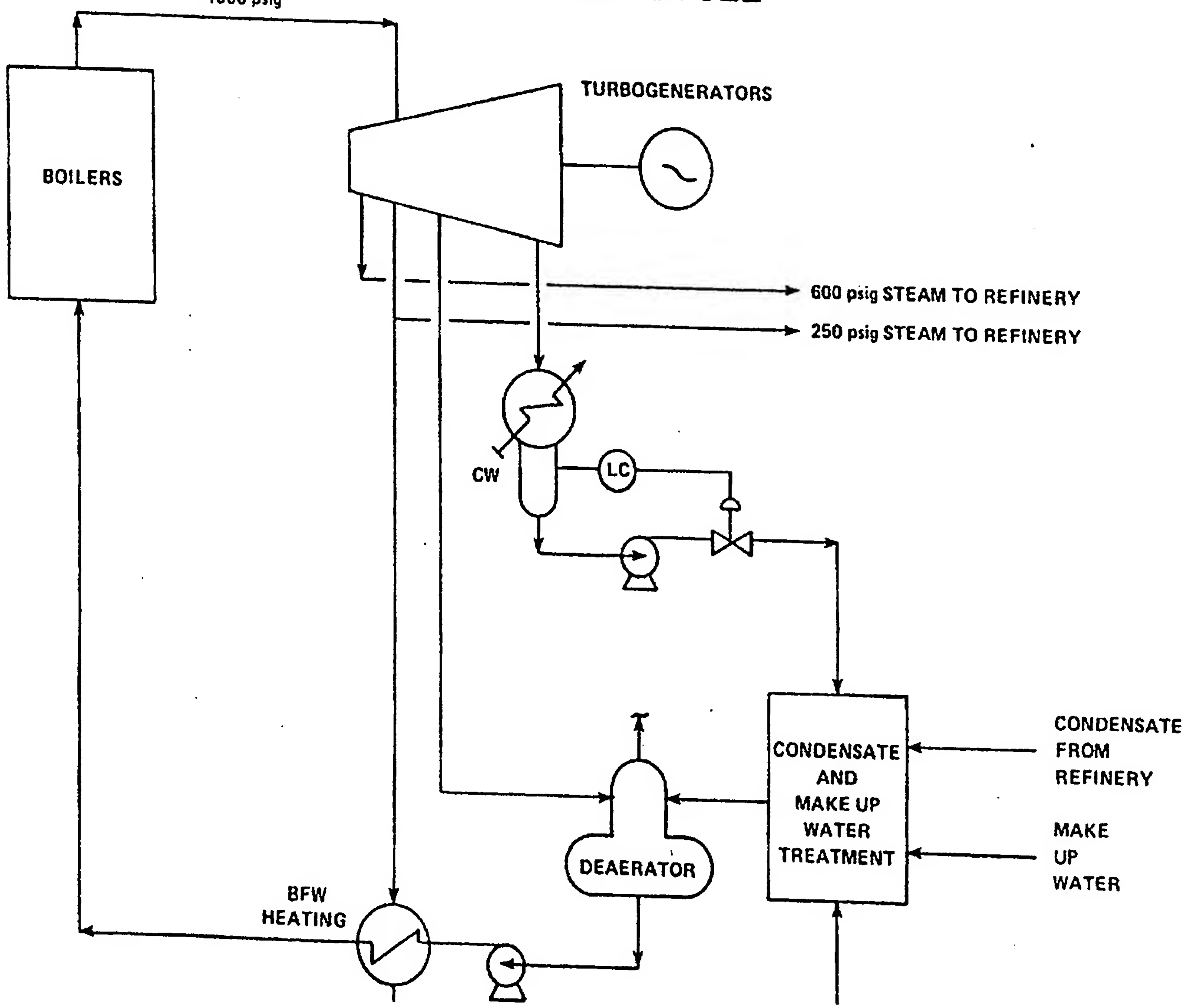

Table 1 summarizes the operating parameters for the Circulating Fluid Bed Boiler and the Pulverized Coke Boiler cases.

The two power cycles are similar in most respects. For the Pulverized Coke Boiler, supplemental firing with natural gas is included to ensure complete burning of the coke fuel. Steam temperature is reduced to 950°F compared to 1000°F for the Circulating Fluid Bed Boiler because of concerns relating to corrosion of superheater surfaces due to the metals content of coke. Overall cycle efficiency is 71.8 percent for the CFB and 68.3 percent for the PCB case.

The CFB boiler plant is based on four boilers rated at 750,000 pounds per hour (MCR) of 1810 psig/1000°F steam. The boilers are sized so that the plant can meet the refinery operating requirements for steam and electricity with three boilers operating and one boiler down for inspection or maintenance. The boilers produce steam which is fed to two extracting condensing turbogenerators. Each turbogenerator is capable of generating 125 MW of power. Normally each turbogenerator produces 91.5 MW of electricity. The additional capacity is provided for flexibility when the refinery does not require the design export steam quantity. When the refinery requires less steam, the steam will be condensed. The additional power produced will be sold to

TABLE 1: SUMMARY OF OPERATING PARAMETERS

	Circulating Fluid Bed	Pulverized Coke
Fuel Fired:		
Coke	2800 T/D	2800 T/D
Natural Gas	0	4200 x 10^6 BTU/D
Utilities & Other Materials:		
Limestone	972 T/D	680 T/D
Water	3400 GPM	4200 GPM
Waste:		
Ash	1188 T/D	1536 T/D (30% water)
Steam Produced:		
Quantity	2,706,000 lb/hr	2,926,000 lb/hr
Temperature	1000 °F	950 °F
Pressure	1810 PSIG	1810 PSIG
Power Generated:		
Gross	183 MW	200 MW
Internal Usage	31 MW	36 MW
Available for Export	152 MW	164 MW
Export to Refinery	145 MW	145 MW
Export to Utility	7 MW	19 MW
Steam Export to Refinery:		
610 psig	400,000 lb/hr/740°F	400,000 lb/hr/690°F
260 psig	1,200,000 lb/hr/590°F	1,200,000 lb/hr/530°F
Condensate Return	800,000 lb/hr	800,000 lb/hr
Overall Efficiency for Power Cycle	71.8 percent	68.3 percent

the electric utility.

The PCB plant consists of three boilers each capable of producing 1,125,000 pounds per hour (MCR) 1810 psig/950°F steam. The boilers are sized so that the plant can meet the refinery operating requirements for steam and electricity with two boilers operating and one boiler down for inspection or maintenance. The boilers produce steam which is fed to two extracting condensing turbogenerators. Each turbogenerator is capable of generating 135 MW of electricity. Normally each turbogenerator produces 100 MW of power. As for the CFB case, this additional capacity is provided for operating flexibility when the refinery does not require the design quantity of steam.

The configurations of the two facilities have been designed with operating flexibility and overall reliability in mind. Operating flexibility is enhanced by the capability to operate easily at different steam export and power production rates than the design scenarios.

Reliability is provided for by building spare boiler capacity and sparing critical equipment to ensure the plants can meet the refinery requirements for steam and power even when one boiler is not operating, or when critical equipment fails or requires

maintenance.

IV. Investment

Investment cost for the CFB and PCB plants was arrived at using equipment factored estimates. This type of estimate produces a capital cost which is considered accurate to plus or minus twenty percent of eventual cost of the installed plant.

To prepare the equipment factored estimate the two plants were defined by performing process studies which set the philosophy and major equipment sizes for items such as the boilers, turbogenerators, cooling tower, fuel handling and storage, etc. Major equipment items were estimated using vendor quotations. An equipment list for each plant was developed and the remaining equipment was estimated using in-house data from other projects for similar equipment. The data is also used to check vendor quotes on major items. The equipment was broken into five different areas to facilitate the estimate. The areas were offsites, steam and power, utilities, environmental and buildings.

Commodity costs associated with equipment include civil, structural steel, piping, instrumentation, electrical, fireproofing, painting and insulation. These costs are estimated

using cost ratio factors, developed by analyzing return cost data for projects of a similar nature. Buildings were estimated on a square foot basis.

Certain utility systems and offsite costs are estimated on a system basis (i.e., water treatment, waste handling, etc.). Take-offs for interconnecting piping were made based upon a conceptual plot plan developed and are used to develop quantities and costs. Field labor costs for installation work were determined by pro-rating from corresponding equipment and materials costs for similar projects. These costs reflect labor wages and productivity anticipated for the Gulf Coast area.

Construction and miscellaneous field expenses including construction equipment, tools and temporary facilities are estimated as a percent of direct field labor costs. Field staff and office costs are similarly figured. Historical information is again used in determining these cost items.

Engineering costs are developed from manhour estimates from each discipline. The manhours were then priced at current rates and non-payroll home office costs added.

All of the above mentioned expenses were summed up to arrive at

an estimated total installed cost (December 31, 1985) for each plant. Once the estimated TIC was established escalation, contingency and financing expenses were added to arrive at an expected investment for the plant.

The results of the analysis are presented in Table 2. Expected investment for the CFB boiler case is $322,000,000; for the PCB case $416,000,000.

V. <u>Economics</u>

<u>Analysis</u>

An econometric model was developed to evaluate the economic performance of the Circulating Fluid Bed Boiler and the Pulverized Coke Boiler cogeneration plants. The proposed facilities were each compared against present day steam and electricity costs taking into account appropriate escalation for inflation. A three year construction period and a ten year project life is considered. Inflation for the 13 year time frame was assumed at 3.5 percent/year.

The model was developed taking into account capital costs, operating costs, expected revenues, loan financing and taxes.

TABLE 2: INVESTMENT FOR COGENERATION PLANTS ($X106)

	CFB Boiler	PC Boiler
Plant Cost	240	310
Escalation	30	40
Contingency	25	30
Subtotal	295	380
Interest During Construction	27	36
Total Capital Investment	322	416

Capital costs include the cost of the plant, interest during construction and cost of site preparation. Working capital is based on interest required to cover two month's revenues. Plant capital costs are used as a basis for depreciation calculations. Sources and uses of funds during construction for the CFB and PCB cases are shown on Tables 3 and 4, respectively.

Operating costs include the cost of coke. natural gas, operations and maintenance, limestone and waste disposal. A sensitivity analysis was performed varying the unit price of coke between $1 and $20 per ton. Limestone and natural gas were priced at $15/ton and $2/106 BTU, respectively. Waste disposal costs for ash and sludge were estimated at $13/ton for the Circulating Fluid Bed boiler dry ash and $15/ton for the Pulverized Coke boiler ash/sludge mixture (30% water). Operation and maintenance are taken as 4 percent of the plant capital cost and include insurance, labor, administration, supplies and spare parts. These costs are in 1986 dollars. The model adds inflation to each cost for each year of project life to arrive at current values for all cost parameters. The model then calculates yearly values for total operating costs.

Revenues are similarly based on present values for Gulf Coast electricity and steam costs. Refinery electric energy costs in 1986

are taken at $0.05/Kwh. Refinery steam costs are $3.75/1000 lb for 600 psig steam and $3.00/1000 lb for 250 psig steam. Cogenerated electricity bought by the public utility is estimated to return $0.04/Kwh. Each product is considered separately. The inflation rate of 3.5 percent per year is taken into account to arrive at annual revenues.

The model is designed so that both operating costs and revenues can be adjusted to reflect plant operating rates above or below the design output. Since sufficient spare capacity was included for each plant studied, operating rate was not varied over the life of the project in this analysis. The economic returns are not particularly sensitive to operating rate unless operating rates are significantly below design. Operating costs and revenues (1986) are presented in Table 5 for the CFB and PCB cases, varying coke costs between $1 and $20 per ton.

The analysis to calculate return on investment is based upon the following parameters. Equity to debt ratio is 25/75 percent based upon total capital cost. Total capital cost includes plant cost, site preparation and interest during construction. Debt is financed by a ten year bank loan at 10 percent interest rate with equal yearly payments to be paid over the first ten years of the project operating life. Depreciation is calculated using the ten year accelerated cost recovery system (ACRS). Taxes are assessed at 46 percent of gross profits.

The model calculates the yearly payments required to satisfy the lo requirements allocating the proper amounts for interest and principal.

On a yearly basis, gross profit is figured by adding total revenu and subtracting total operating costs, interest paid on the bank lo and depreciation. Taxes are then subtracted to calculate net profit Cash flow is arrived at by adding depreciation to net profit ar subtracting the principal payment for the bank loan. The internal rat of return (IRR) on owner's equity is then calculated from the cash flo for a ten year operating period.

Results of Economic Analysis

The econometric model was used to analyze various cases for the CFB anc PCB configurations. Studies were performed to see how different parameters and assumptions affect the economic analysis. The cash flow analysis and the internal rate of return for $10/ton coke are shown on Table 6 and 7 for the CFB and PCB cases, respectively.

For the CFB configuration, using $10/ton coke (1986). projected operating revenues exceed operating costs by 84 million dollars in the first year of operation. This increases to 114 million dollars in the tenth year of operation. Cash flow grows from 19 million dollars in year one to 48 million dollars in year ten. The internal rate of return over this period equals 28.9%.

For the PCB facility, considering $10/ton coke (1986), projected operating revenues exceed operating costs by 79 million dollars in the first year of operation. This increases to 108 million dollars in the tenth year of operation. Cash flow grows from 9 million dollars in year one to 41 million dollars in year ten. The internal rate of return on owner's equity is 16.6% over a ten year operating period.

Comparing the return on investments for the two boiler types, the IRR for the CFB boiler is better than that for the PCB case. This result is attributable to the considerable capital savings associated with the CFB compared to the PCB. High capital costs for the PCB are due to the equipment required for sulfur oxide removal and sludge handling. These costs are avoided with the CFB as no "add-on" equipment is required to control sulfur oxide emissions.

A sensitivity analysis was done to quantify how the internal rate of return changes as the value of the coke fuel is varied between $1/ton and $20/ton (1986 $). The results are presented in Table 8 forr the CFB and PCB cases. As would be expected, when the cost of coke fuel decreases IRR increases and vice versa.

Another analysis was performed to see how IRR is affected by an increase or decrease in plant total capital cost. Total capital cost for $10/ton coke cases was decreased 10% from the base to calculate the low case and increased 10% from the base to form the high case. The results of this analysis are shown on Table 9. For the CFB the ten year average IRR is 28.9% for the base case, 33.3% for the low capital case and 25.0% for the high capital case; for the PCB: 16.6% for the base case, 20.6% for the low capital case and 13.0% for the high capital case.

VI. Conclusions

A study is presented looking at the economics of steam and power cogeneration using fuel grade green coke in a U.S. Gulf Coast Refinery. The economics are not embellished by the various tax benefits that are or were available to projects of this type, but rather looks at the basic common economic driving potentials.

The results of the study show that cogeneration presents a viable avenue to create a profitable market for an otherwise undesirable byproduct of a refinery. The study results could be equally valid for any other complex requiring power and steam in an area where fuel grade coke is available from a nearby refinery.

The better economics shown for the CFB indicate this to be the preferr route. This conclusion is further supported by some operati characteristics of the CFB, especially its flexibility and adaptabili to different fuels. By switching to different fuels the operator coul take advantage of fluctuating relative fuel prices and substitute othe fuels (e.g., heavy residue or even gas) for the coke, if a temporar shortage should present attractive sales opportunities for coke.

While this paper presented two viable means of coke utilization ther are other processes that warrant examination. One of these i combustion in an atmospheric "bubbling" fluid bed (AFB) similar to th one under design for the TVA. This cycle would be similar to the CFB.

Another possibility to utilize the coke is gasification and combustion in a gas turbine based combined cycle. While the investment for such an installation is expected to be higher than that for straight combustion, the additional revenue potential due to improved cycle efficiency may justify the incremental investment.

Acknowledgement

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COKE PRICE 10$/T
CIRCULATING FLUID BED BOILER

TABLE 3: SOURCES AND USES OF FUNDS DURING CONSTRUCTION

(000'S US$)

	YEAR 1		YEAR 2		YEAR 3			
	1ST HALF	2ND HALF	1ST HALF	2ND HALF	1ST HALF	2ND HALF	TOTAL	PCT OF TOT PLANT
SOURCES OF FUNDS:								
Owner's Equity	$5563	$5775	$14664	$15224	$19362	$20102	$80690	25.0%
Bank Loans								
Loan 1	16688	17326	43992	45673	58085	60305	242069	75.0%
Total Bank Loans	$16688	$17326	$43992	$45673	$58085	$60305	$242069	100.0%
Total Sources	$22251	$23102	$58656	$60897	$77447	$80407	$322759	100.0%
USES OF FUNDS:								
Plant Construction	$21834	$21834	$55855	$55855	$69811	$69811	$295000	91.4%
Construction Interest (M-O-P Drawdown) 10.0% int rate: Loan 1	417	1268	2801	5042	7636	10596	27759	8.6%
TOTAL USES	$22251	$23102	$58656	$60897	$77447	$80407	$322759	100.0%

TABLE 4: SOURCES AND USES OF FUNDS DURING CONSTRUCTION

COKE PRICE 10$/T
PULVERIZED COKE BOILER

(000'S US$)

	YEAR 1		YEAR 2		YEAR 3			
	1ST HALF	2ND HALF	1ST HALF	2ND HALF	1ST HALF	2ND HALF	TOTAL	PCT OF TOT PLANT
SOURCES OF FUNDS:								
Owner's Equity	$7166	$7439	$18889	$19611	$24941	$25894	$103939	25.0%
Bank Loans								
Loan 1	21497	22318	56667	58833	74822	77681	311818	75.0%
Total Bank Loans	$21497	$22318	$56667	$58833	$74822	$77681	$311818	100.0%
Total Sources	$28663	$29758	$75556	$78444	$99762	$103575	$415758	100.0%
USES OF FUNDS:								
Plant Construction	$28125	$28125	$71949	$71949	$89926	$89926	$380000	91.4%
Construction Interest (N-O-P Drawdown) 10.0% int rate: Loan 1	537	1633	3607	6495	9836	13649	35758	8.6%
TOTAL USES	$28663	$29758	$75556	$78444	$99762	$103575	$415758	100.0%

TABLE 5: 1986 OPERATING COSTS AND REVENUES

CIRCULATING FLUID BED BOILER (1986)

OPERATING COSTS $MM					
COKE COST $/T	1.00	5.00	10.00	15.00	20.00
COST OF COKE $MM	1.02	5.11	10.22	15.33	20.44
NATURAL GAS UNIT COST	2.00	2.00	2.00	2.00	2.00
GAS COST $MM	0.00	0.00	0.00	0.00	0.00
OPERATION/MAINT $MM	15.20	15.20	15.20	15.20	15.20
LIMESTONE $/T	15.00	15.00	15.00	15.00	15.00
LIMESTONE COST $MM	5.32	5.32	5.32	5.32	5.32
WASTE DISPOSAL $/T	13.00	13.00	13.00	13.00	13.00
WASTE DISPOSAL COST $MM	5.64	5.64	5.64	5.64	5.64
TOTAL OPERATING COST $MM	27.18	31.27	36.38	41.49	46.60
REVENUES $MM					
C/KWH REFINERY	5	5	5	5	5
C/KWH UTILITY	4	4	4	4	4
$/1000 LB 600	3.75	3.75	3.75	3.75	3.75
$/1000 LB 250	3.00	3.00	3.00	3.00	3.00
REF ELC REV $MM	63.51	63.51	63.51	63.51	63.51
UTIL ELEC REV $MM	2.45	2.45	2.45	2.45	2.45
600 REV $MM	13.14	13.14	13.14	13.14	13.14
250 REV $MM	31.54	31.54	31.54	31.54	31.54
TOTAL REVENUES $MM	110.64	110.64	110.64	110.64	110.64

PULVERIZED COKE BOILER (1986)

OPERATING COSTS $MM					
COKE COST $/T	1.00	5.00	10.00	15.00	20.00
COST OF COKE $MM	1.02	5.11	10.22	15.33	20.44
NATURAL GAS UNIT COST	2.00	2.00	2.00	2.00	2.00
GAS COST $MM	3.07	3.07	3.07	3.07	3.07
OPERATION/MAINT $MM	19.20	19.20	19.20	19.20	19.20
LIMESTONE $/T	15.00	15.00	15.00	15.00	15.00
LIMESTONE COST $MM	3.72	3.72	3.72	3.72	3.72
WASTE DISPOSAL $/T	15.00	15.00	15.00	15.00	15.00
WASTE DISPOSAL COST $MM	8.41	8.41	8.41	8.41	8.41
TOTAL OPERATING COST $MM	35.42	39.51	44.62	49.73	54.84
REVENUES $MM					
C/KWH REFINERY	5	5	5	5	5
C/KWH UTILITY	4	4	4	4	4
$/1000 LB 600	3.75	3.75	3.75	3.75	3.75
$/1000 LB 250	3.00	3.00	3.00	3.00	3.00
REF ELC REV $MM	63.51	63.51	63.51	63.51	63.51
UTIL ELEC REV $MM	6.66	6.66	6.66	6.66	6.66
600 REV $MM	13.14	13.14	13.14	13.14	13.14
250 REV $MM	31.54	31.54	31.54	31.54	31.54
TOTAL REVENUES $MM	114.84	114.84	114.84	114.84	114.84

TABLE 6: ECONOMIC ANALYSIS -: PER YEAR CIRCULATING FLUID BED BOILER

(000'S US$)

COKE PRICE 10$/T

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	TOTAL
SALES REVENUE														
VALUE OF PRODUCTS	$0	$0	$0	$124810	$129178	$133700	$138379	$143222	$148235	$153423	$158793	$164351	$170103	$1464195
VALUE OF FEEDS & OPERATING COST	$0	$0	$0	$41040	$42476	$43963	$45502	$47094	$48743	$50449	$52214	$54042	$55933	$481456
MARGIN EX WORKING CAPITAL	$0	$0	$0	$83770	$86702	$89737	$92877	$96128	$99492	$102975	$106579	$110309	$114170	$1945652
Interest on Working Capital 2 MONTHS SALES				$2080	$2153	$2228	$2306	$2387	$2471	$2557	$2647	$2739	$2835	$24403
NET OPERATING MARGIN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
INTEREST ON BANK LOANS DURING OPERATIONS														
Loan 1	$0	$0	$0	$23602	$21181	$18760	$16340	$13919	$11498	$9078	$6657	$4236	$1816	$127086
Total Interest Payments	$0	$0	$0	$23602	$21181	$18760	$16340	$13919	$11498	$9078	$6657	$4236	$1816	$127086
DEPRECIATION	$0	$0	$0	$25821	$45186	$38731	$32276	$32276	$32276	$29048	$29048	$29048	$29048	$322759
INCOME BEFORE TAXES				$32267	$18182	$30017	$41955	$47546	$53248	$62292	$68227	$74285	$80471	$508490
INCOME TAXES				$14843	$8364	$13808	$19299	$21871	$24494	$28654	$31384	$34171	$37017	$233905
AFTER TAX INCOME				$17424	$9818	$16209	$22656	$25675	$28754	$33638	$36843	$40114	$43454	$274585
DEPRECIATION				$25821	$45186	$38731	$32276	$32276	$32276	$29048	$29048	$29048	$29048	$322759
PRINCIPAL PAYMENTS	$0	$0	$0	$24207	$24207	$24207	$24207	$24207	$24207	$24207	$24207	$24207	$24207	$242069
EQUITY INVESTMENT	($11338)	($29888)	($39463)											($80690)
NET CASH FLOW	($11338)	($29888)	($39463)	$19038	$30797	$30733	$30725	$33744	$36823	$38479	$41684	$44956	$48296	$274585

INTERNAL RATE-OF-RETURN ON OWNER'S EQUITY: 28.9% P.A.

TABLE 7: ECONOMIC ANALYSIS - PER YEAR PULVERIZED COKE BOILER

(000'S US$)

COKE PRICE 10$/T

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	TOTAL
SALES REVENUE														
VALUE OF PRODUCTS	$0	$0	$0	$129560	$134095	$138788	$143645	$148673	$153877	$159262	$164837	$170606	$176577	$1519919
VALUE OF FEEDS & OPERATING COST	$0	$0	$0	$50340	$52102	$53925	$55813	$57766	$59788	$61881	$64047	$66288	$68608	$590558
MARGIN EX WORKING CAPITAL	$0	$0	$0	$79220	$81993	$84862	$87833	$90907	$94089	$97382	$100790	$104318	$107969	$2110478
Interest on Working Capital 2 MONTHS SALES				$2159	$2235	$2313	$2394	$2478	$2565	$2654	$2747	$2843	$2943	$25332
NET OPERATING MARGIN	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
INTEREST ON BANK LOANS DURING OPERATIONS														
Loan 1	$0	$0	$0	$30402	$27284	$24166	$21048	$17930	$14811	$11693	$8575	$5457	$2339	$163705
Total Interest Payments	$0	$0	$0	$30402	$27284	$24166	$21048	$17930	$14811	$11693	$8575	$5457	$2339	$163705
DEPRECIATION	$0	$0	$0	$33261	$58206	$49891	$41576	$41576	$41576	$37418	$37418	$37418	$37418	$415758
INCOME BEFORE TAXES				$13398	($5732)	$8492	$22815	$28924	$35137	$45616	$52049	$58599	$65269	$324566
INCOME TAXES				$6163	($2637)	$3907	$10495	$13305	$16163	$20983	$23943	$26956	$30024	$149301
AFTER TAX INCOME				$7235	($3096)	$4586	$12320	$15619	$18974	$24633	$28107	$31644	$35245	$175266
DEPRECIATION				$33261	$58206	$49891	$41576	$41576	$41576	$37418	$37418	$37418	$37418	$415758
PRINCIPAL PAYMENTS	$0	$0	$0	$31182	$31182	$31182	$31182	$31182	$31182	$31182	$31182	$31182	$31182	$311818
EQUITY INVESTMENT	($14605)	($38500)	($50834)											($103939)
NET CASH FLOW	($14605)	($38500)	($50834)	$9316	$23929	$23295	$22714	$26013	$29368	$30869	$34343	$37880	$41482	$175266

INTERNAL RATE-OF-RETURN ON OWNER'S EQUITY: 16.6% P.A.

TABLE 8: SENSITIVITY ANALYSIS OF IRR TO COKE PRICE

COKE PRICE ($/ST)	CFB	PCB
1	33.9	21.4
5	31.7	19.3
10	28.9	16.6
15	25.9	13.6
20	22.7	10.5

TABLE 9: SENSITIVITY ANALYSIS OF IRR TO INVESTMENT

CAPITAL COST	CFB	PCB
LOW (-10%)	33.3	20.6
BASE	28.9	16.6
HIGH (+10%)	25.0	13.0